BRAIN ANATOMY AND PSYCHOLOGY.[1]

> We are not born to solve the problems of the world, but to find out where the promblem begins and then to keep within the limits of what we can grasp.
> —*Goethe.*
>
> Finding the law of phenomena is understanding them.—*Helmholtz.*

AT the close of the eighteenth century, in 1796, a little book appeared in Königsberg dedicated to "Our Kant," and entitled *The Organ of the Soul.*

The author, Samuel Thomas Soemmering, one of the best men of that age, there showed that there is only one part of the brain which can be the seat of the *sensorium commune* (in which he roughly includes intelligence, consciousness, etc., etc.), viz., the fluid which fills its ventricles. That fluid alone, he contends, can bring into relation with one another the extremities of the cranial nerves,—which nerves he had traced as far as the ventricle walls. Therefore this fluid alone, he says, could be instrumental in collecting and uniting into a whole all the varied impressions which act on the organism. The author argues his point in a learned and often extremely clever fashion, and ultimately tries to show that his supposition fulfils all the conditions which the scientific men of his century had thought essential to the working of the so-called *sensorium commune.*

Soemmering's hypothesis is only one of the last of a whole series of hypotheses, which starting from Descartes's views, fur-

---

[1] Translated from the German by O. H. Edinger.

nished matter for thought to men of science during the whole of the last century.

According to Descartes, the soul holds its sway by keeping in touch with certain parts of the brain, and whilst receiving all the sensations transmitted through the nerves, it impresses its will on the muscles. The idea, however, of assigning to the soul a particular seat in the human structure had been abandoned by many, particularly since Christian Wolf by his ingenious arguments had divided the soul into a number of fundamental properties, which were supposed to be located in certain parts of the brain. It is known that Gall's theory was based on similar ideas. But Gall did not start from the existing classification of soul-properties: he based his theory on the simultaneous occurrence of certain peculiarities of character with particular cranial enlargements. This theory would be entirely abandoned, had not Moebius recently undertaken to investigate certain of its bearings, having come across the portrait of a mathematician, whose head presented points of interest in connexion with it.

The researches into the seat of soul-properties have taken a different turn since the experiments of Flourens. He was the first to locate memory, will-power, and consciousness in the hemispheres, leaving the other parts of the brain to account for the so-called lower functions.

Shortly after, it was shown by the discovery of the speech centres by Broca and by a long series of other observations, that certain soul-activities can be traced to particular parts of the brain surface. The great discoveries of Hitzig and Fritsch, locating numerous functions in the forebrain, have practically convinced the majority of investigators that the so-called higher soul-functions must have their origin somewhere in the brain cortex. Flechsig, in the system which he elaborated, dealt scientifically with that idea. According to him, the surface of the forebrain consists of a number of nerve centres, the most important of which are supposed to form powerful apparatuses for associations, without being in direct connexion with the sense-apparatus. The forebrain is again taken to be the chief or only seat of soul-activity. Flechsig defines

over forty separate centres in the brain cortex, barely one-fourth having been recognised by previous writers, but his deductions are by no means universally accepted, and discussion is rife, in the first place, as to his statement that there exist anatomically distinct sense centres and association centres, and secondly as to the value to be assigned to his discovery by embryological methods of a number of separate territories in explaining psychical activity.

At any rate, we are quite certain now that the brain cortex contains a mighty apparatus of ganglion cells, the ends of which can enter into varied relations with one another, as also with the remoter parts of the nerve system.

It is first and foremost to Meynert that we owe the more detailed knowledge of the stratification of the brain cortex. He was also the first to investigate carefully the lines of association in the forebrain, which had been previously discovered by Burdach, Reil, and others.

The most important studies of the cell system of the cortex, and of the varied composition of the cells, were made by Nissl. We had to wait, however, for the truly classic researches of S. Ramon y Cajal in regard to the fibres of the cortex before gaining an insight into the apparatus as a whole.

In considering the enormous amount of work done by physiologists on the function of the cortex, a few names come into prominence, as being those who founded what subsequent collaborators further developed.

They are Hitzig, Fritsch, Munk, Goltz, Ferrier, and Charcot —and we must not forget Horsley—one of the first to carry theory into practice, and who with Bergmann and a few others may be called the founder of modern brain surgery.

The sum total of experiments and the observation of disease, anyhow as far as mammals are concerned, lead us to look in the forebrain for the apparatus, whose undisturbed function is responsible for the normal working of the higher soul activity.

The question has been repeatedly raised: "In what relation do the intellectual faculties stand to the anatomical arrangements in the brain?"

Perhaps we ought first to ask: "What has anatomy to do with psychology at all?"

It has been frequently thought that a continuous series is discoverable, beginning with those functions of the nervous system which are the simplest, going on to those which lead to consciousness, and leading up to the connexion of conscious ideas, and finally landing us in intelligence.

Modern science tells us that such a series does exist, in so far as the nervous system, which is the material basis of "psychical phenomena," develops from a simple apparatus, which gradually grows in complexity.

Attempts to investigate this growth have not been lacking, but people invariably arrived at a point where progress was stopped.

We have no idea how it happens, that a part of the work done by the nervous system leads to consciousness. The attempts to fill up this very sensible gap, which has arisen from the justifiable efforts to reconcile a dualism between body and soul, must be regarded as futile. Even the question as to the nature of consciousness itself which immediately confronts us in such attempts, is so far from being solved, that it is often regarded as altogether insoluble. The difficulty, or absolute impossibility of a solution, arises from the fact that we cannot examine consciousness apart from the outer world. Things appear to us only as our sense organs communicate them. We cannot study them alone apart from all else, but have to content ourselves by simply recognising the connexion between the contents of consciousness and an outer world.

Science can only obtain knowledge of the contents of consciousness, it cannot study the outside world itself, nor yet discover how its manifestations come about.

In reasoning from his own and other work on the subject, a man like W. Wundt draws the modest conclusion, that in matters psychological, the naturalist can only affirm that psychological phenomena run parallel with physiological facts, but that on account of their different natures he has no prospect of ever bridging over the gulf between the two.

Mach also recognises this parallelism, but for him—and by what he quotes from that writer, also for Avenarius—there is no real opposition between physical and intellectual processes. We become aware of both through our sensations, and these are the final and unanalysable elements with which we have to deal as our data, and behind these sensations we cannot go. The question of the relation between body and soul, which has occupied so many investigators, does not exist for those writers; in fact they regard it as a wrong way of approaching the matter.

The naturalist should only busy himself with matter communicated to him by his senses, but of this he must attain full knowledge.

The investigator of nature must often, from purely practical considerations, start from the idea that things are what they appear to be. Only under these conditions can he do any useful work, but he must not ignore the conclusions to which the theory of knowledge leads, if he desire to gain a more extended field of observation. No one can become convinced "*that we neither study things nor their images, but only examine the symbols of them which are given by our sense-organs*"—without recognising that many apparently insoluble questions are raised in vain. But as Helmholtz, and in recent times Albrecht, have shown, we are in a position to show from the results of our study of these symbols and their transformations, that they obey laws.

The relation between brain and soul has been investigated likewise in the field of metaphysics, but I cannot find amongst the various hypotheses any of such a nature as would be likely to help us in our researches.

Really good hypotheses, such as lie anywhere on the path to truth, very often contain a significant hidden element by which further progress can be made.

Men of science appear at present to favor the monistic theory, so energetically upheld by Haeckel. It appears to me, however, that his point of view, whereby consciousness is regarded as being present in all living matter, and as gradually becoming more and more developed, as we ascend the animal scale, lacks an essential

basis, viz., that of proof, that the acts of life of the lower animals have something in them which requires the supposition that they are due to consciousness; nay, I think that on historical grounds the whole question of consciousness has been in a certain way overrated and at all events has not been thought out with sufficient care, because in most observations so far, man has been the starting point. It has been silently taken for granted that what in man we call consciousness, cannot have appeared suddenly, and that therefore the acts of even the lowest form of animal life might easily have been directed by a trace of that element.

"*But it may be possible that consciousness begins at a period when the appearance of particular acts on the part of the animal make its presence probable.*" This probability occurs in the case of animals which possess a brain cortex, and it seems that consciousness develops *pari passu* with cortical development, until we reach its highest known developed state in man.

If we consider matters from this point of view, many acts of animal life lose their puzzling character and are capable of being explained on a relatively well-studied plan. It can also be shown that a similar plan underlies such acts in human life, acts which become conscious. The question, however, is essentially simplified, if our efforts are turned towards the explanation of acts which can be explained on a mechanical basis.

So long as psychology is concerned only with processes which run their course within human consciousness, anatomy can but be of small use to it. In fact it will be more in the interest of science not to try for the present to see, how far this section of psychology can be brought into connexion with anatomical achievements. Without doubt, the day will come when here also the study of the anatomical laws to which it is subject, will become of very great importance, and the ingenious constructive arguments of S. Exner have already shown how much can be explained by simply investigating the mechanism.

The study of psychological phenomena in the highest sense and of the inner perceptions, remains therefore up to now the business of psychology. It is a gigantic task; but much admirable

work has been done during the last fifty years and we may hope for results which will in this field likewise enable us to reduce the fruit of observations to simple laws.

The problem of the nature of consciousness and its relations to the nerve apparatus may for the present be left to those, whose desire for wider results drives them to the framing of hypotheses. The naturalist waits until he sees the road on which he can walk.

Perhaps we shall one day find points of contact, but at any rate we shall get nearer our common goal by keeping on strictly separate roads, by strictly defining the question which brain anatomy can solve and those to which psychology should apply itself, unless of course, new and fresh discoveries about which we have at present no idea, should upset our plans.

Let us then put aside any ideas of consciousness and intelligence and frame the question, which can be answered as follows:

"How far can we explain the acts and the entire character of an animal from the knowledge of its anatomical structure and properties?"

The task would then resolve itself into discovering the mechanism which enables it to receive impressions, to remember them and to turn them into motor processes, and *pari passu* with the anatomical task and dependent on it, at the same time helping it along, there must be the physiological enquiry into the functional capacity both of the elementary organs and their combinations.

The thorough knowledge of a mechanism comprises not only the work which it carries out; it should also include the faculty of foretelling the work it can be put to. Thus, giving the knowledge of the construction of a dynamo, I am enabled to explain the production of the alternating current; further detailed knowledge of the engine's proportions and size, should enable me to tell exactly how much power, light, or chemical work it can be expected to produce. It is by no means Utopian to expect that we shall succeed in time in knowing the nerve-system just as well as the engineer knows his engine.

To the unbiassed observer who without prejudice approaches the study of phenomena, and to him who attaches no more than

necessary importance to the "has been," there appears the necessity of investigating, in the first place, how far the actions of animals can be explained by looking upon them as mere automata.

It may be useful, in order to avoid misunderstandings, to repeat at this point the basis on which we have so far been advancing.

In submitting that certain human or animal actions are the outcome of consciousness, it has to be *proved* in each case that that is so.

Where such proof cannot be furnished, it will be useful to discover the mechanism which can perform the particular action, without assuming the presence of consciousness at all.

The human frame includes several such mechanisms; it will therefore be useful, for the point at issue, to study it likewise as a machine.

It would, however, be most premature to try to explain the working of the human soul by mechanical arrangements.

Even if the results of our scientific training point to such a view, it cannot be too positively affirmed, that we have no basis whatsoever upon which it could be justified.

I remember being amused at Bellaggio in watching the play of artificial lizards for sale near the lake. The simple contrivance of a stretched rubber band and its subsequent loosening, caused these tin imitations to move in an absolutely natural fashion. Shortly after, whilst ascending the hill, I saw numerous lizards basking in the sun; and just as the india-rubber band had in the case of the imitations loosened limbs and tails, so now my shadow, or approaching step, appeared to have set in motion a mechanism which caused the live creatures to move away, one like another, in the same manner and at the same moment.

It is our business to discover how such movements originate; but it would be for the psychologist to ascertain whether, apart from the mechanical stimulation, other motives are at work, such as fear; wish to escape, former impressions, etc., etc.

Anyhow the scientific point of view is this: If our observation goes to prove that, let us say, a particular optic stimulation will

invariably have precisely the same effect in causing certain movements, then the assumption that consciousness simultaneously plays a part in that process would have to be *proved*. It would be most unscientific to assume such influence, merely because it may be traced in the human frame on similar occasions. To prove such an assumption (a very difficult proof) would be the business of those who persist in carrying human experiences into animal physiology, and thereby rather hinder than advance progress.

Let there be no misunderstanding; I am not disputing any of the prevailing philosophical views. All I wish to call attention to and to recommend, is a new method of research. I am far from desiring to deny the presence of consciousness; and the position which I take up, is aptly expressed by the following quotation from Spinoza: "Et enim quid corpus possit nemo hucusque determinavit; hoc est neminem hucusque experientia docuit quid corpus ex solis legibus naturae, quatenus corporea tantum consideratur possit agere et quid non possit nisi a mente determinetur. Nam nemo hucusque corporis fabricam tam accurate novit ut omnes ejus functiones potuerit explicare."

Some phenomena in the lives of lower animals which appear the distinct outcome of a free will, have been proved to be the result of chemical or physical laws; they could therefore be recreated under analogous conditions with the same certainty as the movements of iron filings under the influence of a magnet.

Such movements are described by the term "tropisms." The nature of tropisms remains to be investigated, but the process at work has been thoroughly sifted, chiefly by Engelmann, Loeb, and Verworn; and we have learned that light, warmth, the electric current, and the law of gravity are exercising their influence on lower animals exactly as they do in the case of plants.

Hardly twenty years ago Bunge quoted an observation of Cienkowsky's, relating to an infusorium, the Vampyrella, which chooses amongst a mass of seaweed a particular kind, the Spirogyra, into which it burrows. He uses this fact for proving the presence of psychical qualities in creatures, at the bottom almost of the animal scale.

But we know now, that many chemical substances attract or repel the lower strata of plants and animals, and we further know that certain plants produce these substances. Thus the whole process becomes clear, if not explained, and it certainly is no longer necessary to attribute powers of discernment to an infusorium.

Loeb has made use of these tropisms for compelling creatures to useless or even detrimental actions. Thus certain tubicolous worms draw themselves under all circumstances into any apertures which may be accessible; they will even crawl into brightly lit-up glass tubes, where they are bound to perish, and this solely, because the force which compels them to enter the tube is greater than the stopping power of the light.

Other actions of lower animals extremely logical in appearance can be imitated. Thus Rumbler constructed amœbas from chloroform drops and other matter. The artificial things built houses of grains of quartz just like the real creatures. They flowed round small bodies, and if these possessed certain chemical affinities, they absorbed them, just like real amœbas. Yet nobody would think of attributing reason to these automata, nor has it yet been proved that the identical actions of the real creatures are attributable to other than mechanical and constructive qualities.

Loeb maintains the hypothesis that all animal actions can be reduced to tropisms. To him the nerve system is but a strengthening and regulating element, whose co-operation with the mechanism engenders more highly developed and more varied activity. He tries to prove this theory in an interesting work, but to me he appears to be going rather too far, because he does not attach sufficient importance to the peculiar qualities of the nerve system. He maintains that animals possessing a nerve system could get on just as well without it; he cites the frog-spawn whom Schaper had deprived of their brain, and who in spite of it and with spinal cord degenerated, very cleverly avoided the touch of the needle; on referring to Schaper's work, I have my doubts as to whether the spinal cord can be assumed to have been out of function. I take it from Schaper's illustrations that the apparatus proper of the spinal cord—viz., the one not dependent on the brain—had

been preserved, and that therefore the spawn was merely in the same condition as other animals which have been experimented upon after being deprived of their brain.

Most of the so-called soul-life is dependent upon the nerve system. How much do we know about the latter, and in what direction does further work lie?

We may take for certain the fact of transmission of an outside stimulation to some cell, and the possibility of emanation from that cell, or from others connected with it, of motor phenomena—the reflex of the first reaction; we may likewise assume the presence of some mechanism for the working of it all.

It is certain that a great number of complicated phenomena, although apparently impossible without the intervention of will-power or consciousness, can be traced to Reflex Actions.

A large amount of work has been done since the time when the well-known diagram was established, where a nerve, starting from the periphery, joins a ganglion cell, whilst at the other end of that cell another nerve starts for the motor apparatus.

This simple theory has grown in complexity. It has been found that the effect of a stimulation is simultaneously conveyed to a plurality of cells. These pluralities or plexes, their arrangements, connexions, and relations with one another and with fibres have been investigated. More recent experiments of Apathy and Bethe have proved a perfect system of fibrils within the nerve-cell, emanating from various parts, crossing and re-crossing each other, so that each nerve-cell may therefore be considered a nerve centre by itself. Nissl has told us of the presence in between these fibrils of different substances subservient to life and function of the cell; part of these substances very probably contain the elements of chemical energy necessary for the working of the cell functions.

The anatomical problems which remain to be solved, have reference to the minute relations between those various parts. There is a difference of opinion as to whether the individual cells and their annexes are physiological entities, and therefore theoretically capable of individual action; or whether they are merely the points and crossings of the complicated fibre apparatus which goes

to make up the nerve system. The majority of scientists incline towards the former opinion. It having been proved that the cells with their annexes are at least biological entities, which can perish singly, a certain individuality must be attributed to them, even if further researches should prove that Reflex Actions mainly depend for their working upon the fibrillar apparatus.

Most important to psychologists is the following question, the solution of which will have to be furnished by the physiology of the nerve system. In how far may the course of nervous processes be changed by the fact that the physiological elements have been previously affected by particular stimulations, and may we not assume that such previous stimulations will under certain circumstances cause changes, which will come into play during the course of other or similar, but later occurring, processes?

The question embraces the problem of memory, which may therefore be investigated without touching on the larger problem of consciousness. Physiology, whilst studying the phenomena known as brain-paths, has taken the first step towards the solution of this matter.

The researches into Reflex Actions used to be undertaken chiefly for physiological reasons. In the case of many of them we know the exact conditions under which they take place, under which they can be accelerated or prevented. But the remarkable researches into the spinal cord by Pfluger and von Goltz have given proof that much higher problems may be approached in connexion with investigations into reflex-phenomena. In this respect we have profited largely by experiments made on lower animals. We have, in numerous instances, succeeded in tracing actions of highly reasonable and apparently logical nature to comparatively simple anatomical arrangements.

The researches of Loeb, Friedlander, Bethe, von Preyer, and von Uexkill have opened new roads and given rise to new views. It has been proved that certain stimulations will with certainty start into activity particular reflex-arcs; that, for instance, the chemical stimulation caused by the reception of food will instantly set mouth and jaws into sympathetic motion. A bee's mouth will

keep sucking honey even after the head has been cut off the body; other stimulations will cause a forward movement of the head and such movement can be of sufficient force to lead to very curious results. Thus a planaria on which two heads have been bred will sometimes tear its own body in the effort of moving each head separately. (Loeb.) Two arms of a star-fish, squeezed into a narrow bottle, will drag the whole body after them, although the creature must inevitably perish. The head part of a lob-worm, separated from the body and covered with sand on the slate, will immediately start a boring movement, and the lower part of a bee when cut off from the body will apply the sting, if interfered with. This is evidently the mechanical result of a particular stimulation and has nothing in common with anger, venom, or self-defence.

Such particular reflex movements, the apparatus for which may sometimes be separated from the body without detriment, are well known, and it has been possible, as in the case of Carcinus mænas (Bethe), and in the case of other crustaceans and worms (Loeb), to explain almost the entire demeanor of an animal by single actions of anatomically definable mechanisms.

In most cases we have to do with a composite nerve-system: the details of some nervous systems are accurately known to us so that we can, for instance, picture to ourselves how the crawl of a worm is caused by some particular stimulation; what the mechanism is like, that works the co-ordinated movements of first the front and then the lower parts. Sometimes the reflex apparatus placed outside a somewhat unimportant nerve-system, maintain a great degree of independence; as, for instance, in the case of the sea-urchin (Uexkill), which is provided with a number of separate nervous mechanisms, each working independently and supplying the animal with food, cleansing it, and moving it about. A dog, says that author, moves its legs in walking. The sea-urchin is being moved by its motor apparatus. He calls such an arrangement a reflex-republic.

We have, of course, not nearly reached the end of our researches, and numerous actions of the lower animals are still far from being explained by any facts within our present knowledge.

Quite apart, for instance, from the somewhat complicated actions of the ants—actions which we can only partly explain, there are numerous plain and simple movements, the causes of which remain obscure; amongst these I cite the propensity to escape; most animals move more or less rapidly away from sudden outside influences. This propensity is already exhibited by fish embryos, and was prominent in the case of Schaper's brainless frog-larvæ with diseased spinal cords; likewise quite unexplained are the motives which cause migrations and their directions; and many other matters.

Our researches and consequent deductions have demonstrated that as the reflex mechanism can be inherited, so can there be heredity of the functions which emanate from it, even when they are very complicated and irreducible to simple stimulations.

These inherited actions, simple or complex, may be brought under the much abused term of "instinct." We thus obtain a definite and *objective* way of looking at those combined reflex actions which the individual, like all other examples of his species, brings ready made with him into the world, and also at such new qualities as he may acquire in the course of his individual existence. Proceeding therefrom we can analyse each single action of the animal as to, (1) whether it is based on a single spontaneous reflex common to a large group of animals, (2) whether it is based on a more complicated phenomenon produced by the whole group in an identical manner, and (3) whether the process is such as can have been acquired only by the individual, in which case it remains to be ascertained in what degree the nerve-system of the individual is able to receive new impressions, to retain them and to reproduce them subsequently in similar or modified associations.

A recent very interesting paper on the biology of the honey-bee by von Buttel Reepen, arrives at the conclusion that these insects are not pure reflex machines but that besides numerous inherited reflex actions, they possess signs of a memory; that they can learn and are able to form associations from impressions. This discovery appears quite intelligible without assuming the co-operation of consciousness.

Single reflex apparatuses are present in the intestines, the heart, and the skin of all vertebrates. Most of them, however, have their seat in the central nervous system.

With our present anatomical and physiological knowledge of the spinal cord and the oblongata we may take it for granted, that these portions of the nerve-system contain only apparatus working according to the reflex type. We have even succeeded in discovering the mechanisms for many functions and in locating their position in the general apparatus.

The study of the spinal cord has resulted in such intimate knowledge of that organ, that it may now be reckoned amongst the most transparent parts of the human body. Not only do we know to a certain degree the individual mechanisms which it contains, we can also diagnose their position and we know their connexions with other parts.

Many experiences of investigators with regard to reflex actions are now receiving their anatomical explanations. I may be allowed to cite one, because it is particularly suited to show that ideas are open to modification which are based on purely human points of view.

It is a well-known fact that frogs couple in spring-time. No knife, nay, no power on earth can part the loving couple. Earlier experiments by Goltz have shown that at the coupling-time the skin of the female even though she be dead, nay, even the skin of a dead male if stuffed with ova, gives rise to the reflex action of embracing, as soon as it is brought into contact with the inner side of the frog's feet! We might cut up the frog from behind up to the cervical cord, or crush it from head downward, the result will remain the same; i. e., the ring formed by the cervical cord and the two arms, even when entirely separated from the rest of the body, will continue in the position and action of the coupling frogs. Now, if in order to explain this action in the light of consciousness, we were to locate that particular consciousness in the neck, it would be necessary to find some sort of *proof* for such an assumption. But the naturalist must be satisfied with the simpler conception,

i. e., the purely mechanical nature of the embrace, as long as the latter explains all the visible manifestations.

Whether the spinal cord can retain impressions, use and reproduce them, or, to put it briefly, whether the spinal cord can "learn," remains a problem. The experience gained in the practice of complicated movements points to an affirmative solution. But special experiments would be welcome. It might be possible, for instance, to find out whether a very familiar movement, the result of long practice, could still be carried out after the brain has been removed, be it only for a few seconds (as is the jump of a beheaded rabbit, or the swimming of a decapitated duck).

Much therefore remains to be done; still, we know already in what direction to look for new results, and how the actions originate, which are based on the reflex apparatus of the spinal cord and the oblongata.

All the anatomical researches in regard to lower animals, and into the spinal cord of the higher ones, tend to prove that nothing more determines the capacity of the mechanism than its measure of relation to other mechanisms.

Anatomy has shown us in increasing numbers the channels through which such relations or associations take place. The nerve apparatus grows in the rising animal scale by a process of superposing new apparatus over the lower ones, either joining those together, or forming new and varied centres of associations and brain paths.

My own researches during the last twenty years have demonstrated that the bulk of the nerve centres and association apparatus situated in the spinal cord and further forward towards the corpus striatum, have in principle a similar structure with all vertebrates.

There is nothing to show that this very constant structure varies anywhere in its functions. On the contrary, it is to be assumed that the same mechanism will originate the same actions, notwithstanding the fact that the function of an apparatus may on the appearance of a new apparatus lose importance in proportion as that of the latter grows.

No observations now prevent our drawing conclusions from the nerve system of an animal about its capacities in certain directions, when we know of an analogous structure and its functions in the case of another animal.

On the whole, we know very little of the working of those portions of the vertebrates' brain which are situated between cortex and oblongata; and therefore it would be interesting to know more of the character of those animals which have no cortex. It would perhaps be possible to use the knowledge obtained in that direction in the study of higher animals; in whose case the large cortex apparatus completely blots out any probable action of the lower centres.

This led me to investigations into the psychical endowments and limitations of teleosts—vertebrates which are not yet possessed of a cortex. The observations have proved that fishes are only able to form very few associations. They are reflex machines, exhibiting a certain number of co-ordinated actions, which may be described as manifestations of instincts; they have very little capacity for learning; they find out the conditions under which they are fed, and after the repeated concurrence of these conditions they swim up to the feeder just as before they approached the natural food. They learn to forget fear. That is about all I have been able to gather from numerous experiences communicated to me from hundreds of sources.

A considerable change takes place on the appearance of the cortex. When this apparatus (first markedly pronounced in the reptile) is superposed over the other parts of the brain and is gradually added to by other particular parts, then the individual is placed in possession of a number of new mechanisms, all of which are joined to, or connected with, the lower central apparatus. We know the particular lower centres with which the earlier cortex parts are connected, nay, we have learned that in the rising animal strata the cortex grows gradually round the lower portions, simultaneously connecting with other and more distant points in the brain.

Anatomy has already pointed out that in the case of the lower

vertebrates, mainly the olfactory nerves connect by their ends with the more complicated cortex apparatus, that first in the case of birds powerful brain paths are developed from the end of the optic nerve to the cortex.

Nay, some of those very early brain paths have been traced in the human brain, and the possibilities of associations, even in the case of the very earliest cortex, are of a complex and far-reaching nature—the results merely of structural improvements. This has been proved by numerous researches into the pallium of the mammalian brain.

Already in the case of the amphibious animals and certainly upwards from the reptile, the amount of fibrous structure leading up to the brain cortex bears no proportion to the powerful fibre and cell apparatus situated inside it. It is impossible not to conclude that this mechanism offers the possibility of numerous associations from impressions conveyed through a very few channels, and that, as Flechsig has it, the cortex is merely an apparatus for forming associations.

We ignore the actual processes which take place inside the cortex. But according to present experiences we must attribute at least two qualities to it. Firstly, the faculty in a very high degree of retaining impressions; and secondly, the faculty of associating them with one another; we may further attribute to it the faculty of somehow turning sensory stimulations into movements or of preventing movements. There is no reason for assuming that either cortex or any other part of the nerve system has the faculty of creating movements without the previous reception of sensory impressions. On the contrary, everything seems to point to the conclusion that what we call free will is but the final state of a long series of processes, which had their starting-point in sensory receptions.

We know already so many connexions between the brain cortex and the lower centres, as also between the individual parts of the cortex itself, that it has been possible by careful localisation to study very complicated mental functions, such as speech, seeing, and reading. With respect to certain parts of that marvellous ap-

paratus—man's brain—we are getting near the completion of our experiments on the main features of the mechanism. We have, for instance, an approximate idea of the apparatus and associations which are required for turning a command, given in writing, into action.

Psychological analysis and anatomical researches here meet on common ground—numberless investigations have explored it—but if on the whole the results are not such as one might well desire, the cause for the shortcoming is to be found in the enormously complicated nature both of the psychological phenomena and of the anatomical conditions.

"*The task which psychology has sometimes set itself of trying to obtain a closer knowledge of man's soul-life by help of the construction of his brain has proved to be far too high.*" Nor have the investigations into animal psychology been altogether of a profitable nature, because they have chiefly been carried out on mammals.

But anatomy has become our guide on a new road, which is likely to lead to useful results; we know that the lower vertebrates as compared with mammals, and still more as compared with man, are capable only of extremely simple and transparent actions. If we try to submit the soul-life of these animals to a much closer observation than has so far been granted to it, we find ourselves confronted by a comparatively simple problem; and we know now so much about the construction of the lower vertebrates' brain, that we are in many respects more familiar with the brain, say of a lizard, than with that of man. We must therefore try to see what fishes, amphibious animals, and reptiles are able to do, and how far their behavior can be explained by the construction of their brain. The problem is not such a difficult one as it might appear at first sight.

In reviewing the existing knowledge of the lives of those creatures, we find that they have rarely been under unbiassed observation, and that conditions have nearly always been very unfavorable.

In the first place, and guarding against the common mistake of constantly substituting human sensations and desires, it is soon apparent that a great deal, including search for and seizing of food,

can be ascribed directly to reflex movements. The frog does not search for the worm, but the moving worm, when sufficiently perceived by eye and ear, sets into motion the process, on the frog's part, of catching it. This can easily be perceived in places where animals are kept in a cool temperature, and processes run their course slowly. The well-known fact that lower animals mostly feed on moving objects is thus explained. It is easy to deceive them by setting objects in motion. Artificial bait-fishing is based on the same principle.

Another fact, much overlooked, but considerably facilitating research, is, that all lower animals, when observed under natural conditions, lead a lethargic existence from which they are only roused under the influence of hunger, the sexual instinct, or the stress of weather.

Tritons and salamandra whose nerve system is no more developed than the human nerve system in the second month of gestation, are practically free embryos spending eleven twelfths of the year in sleep. The majority of our snakes probably do so likewise. As far as I can see, both quality and quantity of whatever action is developed by the lower animals, has been over-estimated, because they have generally been observed in a roused state, but chiefly because notice has only been taken of what they actually did, whilst the enormous extent of time spent in inactivity has not been taken into sufficient consideration. It will be admitted that even this unpsychological method of observing the soul-life of animals may lead to results useful in simplifying and clearing up truly psychological problems.

We have already seen how the question of memory can be reduced to points which may be studied without assuming the presence of consciousness, if we only accord to the term memory a broader meaning than conscious reminiscences. Another instance is furnished by the question whether the lower animals suffer pain. Man cannot imagine pain which he does not perceive, and he therefore sometimes calls anæsthetics, painkillers. Animals have always been supposed to feel pain, but it has not yet been proved that the worm turns because he feels that he is trodden on.

If we cut (Norman) the Allolobophora caliginosa (of the earth-worm species) into halves, the frontal half will merely crawl away, whilst the other half will twist and curl itself about as if it alone reacted on the strong stimulation of the cut; but we find by continuing the cutting-up process, down to the most infinitesimal sections, that the hindmost pieces will always continue those movements which are commonly supposed to indicate pain, whilst the frontal parts resume their more quiet behavior. It will be admitted that the mechanism underlying those movements can be anatomically explained, and that it ought also to be possible to determine the physiological laws to which the stimulation on the hind parts and the stoppage of the movements in the frontal sections are subject. But what reasons have we for assuming that those movements are accompanied by pain? We have not even analogous cases to fall back upon for comparison! If man or the higher animals in case of severe stimulations make certain movements accompanied by pain, that is no reason for assuming similar effects in the case of cortexless lower animals; we know that the identical movements are often made under similar stimulations, without the accompaniment of pain; take the struggling movements of a person under the influence of anæsthetics, or take the case of a person with the lower portion of his body in an anæsthetic state; he will draw in the foot under the prick of the needle, without feeling pain, in exactly the same way as when actually feeling it.

I feel confident that a continued study of the psychic behavior of animals with simple actions and of simple brain construction, will lead to results, which will facilitate the problems of human psychology.

The main point is to find out, up to what point the action of vertebrates can be explained by known anatomical mechanisms. Even then we shall most probably arrive at a point in our researches where the assumption of consciousness becomes a necessity. But that point is being moved farther and farther away, and if we faithfully adhere to our methods, the explanatory process will steadily advance farther still.

When we arrive at the point at which actions can no longer be

explained, except by assuming a certain amount of consciousness, then it will be time to take the opposite course and follow downward in the animal line that which still remains obscure. We can scarcely suppose that consciousness comes suddenly into existence at a given stage of development.

So far, the practice of explaining animal manifestations by human experiences has led to few results; it is therefore surely time to try and form conclusions by going the other way about, working upwards from below.

An entirely new field for research is thus opened up, and I hope to have shown in the foregoing where its points of contact lie with what up to now has been called psychology. The day will come when the two branches of the same science will join hands for the solution of the higher problems.

L. EDINGER.

FRANKFORT.